A REGIONALIZED ASSESSMENT OF THE INFLUENCE OF RURAL NONPOINT SOURCE POLLUTION ON THE ECOLOGICAL INTEGRITY OF STREAM ECOSYSTEMS AND AN EVALUATION OF ASSOCIATED POLLUTION CONTROL MANAGEMENT

Proposal Addendum

Submitted to the U.S. Environmental Protection Agency

Region VII

by

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The duration of the investigations outlined in this proposal is one year, and so the budget provided is for a single year only. However, because of the problems outlined on page 16 of this proposal, it will not be possible to complete all of these projects during a single year and still reach our objective of providing recommendations for mitigating the effects of nonpoint source pollution on aquatic ecosystems. Therefore, we will request a renewal and refunding of the project for a second and third year. In fact, we anticipate that a request for funding will be made in years four and five.

The four major initiatives outlined in the proposal will be continued during the subsequent years of funding. A large part of the need for additional years of sampling is to experiènce and sample as much climatic, hydrologic, chemical, and biological variability as possible. Consequently, the core of activities for the watershed monitoring, remote sensing of lakes, rivers, and terrestrial vegetation canopies, and the landscape regionalization initiatives will remain the same throughout the three years of funding. However, in the years subsequent to the first year, as more data are collected, we expect to be able to perform more thorough and detailed analyses which will establish the cause and effect interactions among land use/land cover classifications, nonpoint source pollution, and ecosystem structure and function. This, in turn, will allow us to provide recommendations for mitigating the effects of nonpoint source pollution on the ecological integrity of aquatic ecosystems. Realistically, enough data should be collected by the end of the second year to allow us to make reasonably reliable estimates of the effects of nonpoint source pollution on aquatic ecosystems.

We anticipate expanding our efforts to investigate the effects of urban nonpoint source pollution on aquatic ecosystems. It is not known exactly when this will occur, however, we feel that with the recognition of the severity of the nonpoint source pollution generated by urban areas, and the new stormwater runoff regulations, it will become necessary to initiate an investigation of this problem. We have designed our approach (integrated ecosystems approach) so that we can transfer the methodologies and techniques for studying nonpoint source pollution to urban watersheds without any loss of time or continuity.

Investigating the effects of nonpoint source pollution separately in urban and rural watersheds will allow us to fully understand the problems associated with each environment. We can then expand the size of the study area and the scope of the project to include watersheds containing both rural and urban landscapes. Delaying the investigation of urban nonpoint source pollution until the second or third year also will provide us the time to acquire some analytical equipment, e.g., a mass absorption spectrometer, that will expand our capacity to detect specific pollutants that are more common in urban areas (e.g., heavy metals) than rural areas.

Year One Project Assignments By Percent Participation

Project	KU Task	KU Project	UNL Task	UNL Project	ISU Task	ISU Project	Task
Watershed Monitoring	40	(8)			60	(12)	100
Remote Sensing Streams & Rivers	80	(16)	20	(4)			100
Vegetation Canopies	90	(18)	10	(2)			100
Regionalization			100	(20)			100
Mechanistic	50	(10)			50	(10)	100
	260	(52%)	130	(26%)	110	(22%)	500
	$652,056.		$322,944		$275,000		$1,250,000

It is not possible to provide a breakdown of the budget by projects because the projects are so closely interrelated and data collected for one project will be used in other projects. For example, fish collected for the long-term watershed monitoring investigation will be used in the development of the modified Index of Biotic Integrity, one of the projects within the mechanistic and small-scale process investigation. Consequently, it would be impossible to assign exact proportions of the budget to specific projects. However, we provide a general list of responsibilities for each university for each project. Specific activities within these general categories can be found in the original proposal.

Watershed monitoring

KU - water quality analyses, field sampling (6 watersheds), GIS land use/land cover database development, data management and analyses

ISU - field sampling (9 watersheds), GIS land use/land cover database development

Remote sensing - streams and rivers

KU - mesocosm preparation and manipulation, primary production sampling, water quality analyses, data management and analyses

UNL - spectroradiometric measurements, data management and analyses

Remote sensing - vegetation canopies

KU - field sampling of vegetation, laboratory analyses, data management and analyses

UNL - spectroradiometric measurements, data management and analyses

Regionalization

UNL - all activities

Mechanistic and small-scale processes

KU, ISU - all activities

Provided below is a list and brief summaries of the major activities involved in each of the investigations. The list is organized by quarterly time periods, which coincide with the quarterly sampling that will be conducted in each watershed. However, because many of the activities are repeated each quarter, summaries are provided only for the first time that the activity is listed.

Quarterly activities by project

Watershed monitoring

June 15 - September 30

O Acquire MS/GC for chemical analyses, automated water samplers, and aerial photography - We expect the bid process for the equipment to be time consuming and have been told that it may take up to three months for delivery of the equipment.

○ Select watersheds for long-term monitoring, contact local SCS personnel and the land owners to establish routes of ingress and egress to the streams.

○ Ground truthing within watersheds requiring visiting the watersheds to locate and verify various landscape features such as livestock operations, new construction, and other features not readily detectable from aerial photography or USGS topographic maps.

October 1 - December 31

○ Autumn watershed sampling - Begin seasonal sampling as described in the workplan.

○ Build GIS land use/land cover databases - Begin digitizing various landscape features such as soils, topography, and stream channels, as well as digitizing the mylar overlays from the aerial photography.

○ Collect water from runoff events for chemical analyses - Rainfall runoff from the landscape to the stream network will be collected and analyzed as described in the workplan.

○ Ground truthing within watersheds

January 1 - March 31

○ Winter watershed sampling (if possible)

○ Build land use/land cover database

○ Data input and analyses of autumn sample - Data will be transferred from field data sheets to the computer where it can be summarized. Analyses of these data will begin.

○ Ground truthing within watersheds

April 1 - June 15

○ Spring watershed sampling

○ Build land use/land cover database

○ Ground truthing within watersheds

○ Data input and analyses of winter sample

○ Collect water from runoff events for chemical analyses

○ Identify data gaps - Examination of our sampling protocol to determine if additional parameters should be included in the field sampling or water quality analyses.

○ Prepare year-end report of activities

Remote sensing - Close range remote sensing of streams and rivers

June 15 - September 30

○ Chlorophyll and sediment dilution manipulations in mesocosms - After the development of normal aquatic communities, additions of sediment, or nutrients to stimulate primary productivity will be performed in preparation for the spectroradiometric measurements.

○ Atrazine additions to mesocosms - In an effort to determine if spectral analysis can detect nonpoint source pollution, atrazine will be added to some mesocosms.

○ Spectroradiometric measurements in mesocosms - Spectron 590 with a boom-mounted sensor head will be used to collect spectral reflectance data.

October 1 - December 31

○ Autumn spectroradiometric measurements in mesocosms

○ Ground truthing (measurement of primary productivity) - Harvesting of vegetation and measurements of primary productivity will be made as outlined in the proposal.

○ Data reduction and analyses -

January 1 - March 31

○ Data reduction and analyses

April 1 - June 15

○ Identification of data gaps

○ Prepare mesocosms for summer manipulations

○ Prepare year-end report of activities for EPA

Remote sensing - Close-range remote sensing of terrestrial vegetation canopies

June 15 - September 30

○ Summer spectroradiometric measurements on sample plots using the boom-mounted sensor head

○ Vegetation sampling and harvesting as described in the workplan

○ Data reduction and analyses - Summarize the information content contained in the original spectral reflectance data, as well as determine which individual bands provide the greatest ability to discriminate among vegetation types (canopy types).

October 31 - December 31

○ Autumn spectroradiometric measurements on sample plots

○ Vegetation sampling and harvesting

○ Data reduction and analyses

January 1 - March 31

○ Data reduction and analyses

April 1 - June 15

○ Spring spectroradiometric measurements on sample plots

○ Identification of data gaps

○ Prepare year-end report of activities for EPA

Landscape regionalization

June 15 - September 30

○ Literature review - Investigate sensor-landscape interaction, methods of landscape regionalization, techniques for characterizing landscape structure and relationships to nonpoint source pollution.

○ Define study areas - Watersheds identified in the watershed monitoring project will be targeted for detailed analyses.

○ Identify linkages to nonpoint pollution models

○ Participation in the National Center for Geographic Information and Analysis International

Workshop on Integrating GIS and Environmental Monitoring, Boulder, CO; meet with EMAP and other collaborators to further develop interactions.

○ Initiate formal interactions with Nebraska Department of Environmental Control, USGS, USDA/SCS, and other agencies in Region VII.

October 1 - December 31

○ Begin acquisition of remotely sensed data, maps, and other ancillary spatial data

○ Begin software development to implement methods for landscape structural characterization, regionalization, modeling, and visualization

○ Initiate database development on small watersheds

○ Begin development of image analysis strategies and methods for extrapolation between scales of landscape observation

○ Begin prototype definition of enhanced landscape regions for Region VII

January 1 - March 31

○ Attend International Association for Landscape Ecology meetings in Corvallis, OR; meet with collaborators at EPA-Corvallis

○ Begin tests of software developed previously, continued development of software

○ Completion of literature review

○ Initiate development of hierarchical databases for small watersheds

○ Test and evaluate image analysis strategies and prototype methods for scaling up from ground level to a regional perspective

April 1 - June 30

○ Development and evaluation of image analysis strategies and GIS databases

○ Identification of possible software links to nonpoint source pollution models - Prepare for testing on selected small watersheds.

○ Prepare enhanced ecoregion map for Region VII based on first year's data - Prepare structural regions map for Region VII; evaluate maps with EPA, state, and university collaborators.

- Prepare manuscripts on first year's work for presentation and publication
- Prepare year-end report of activities for EPA

We anticipate that the individual projects covered under the mechanistic and small-scale process initiative (see below) will be completed within the year. These projects have been designed either to investigate the ability of specific parameters, e.g., the Index of Biotic Integrity, to serve as indicators of ecosystem structure, or to investigate the functional relationships among structural components so that it is possible to connect these components in our structural equation modeling efforts in a manner that reflects true ecosystem structure and function.

The individual projects that are included within the mechanistic and small-scale process initiative will be completed using data collected during the regular sampling conducted as part of the watershed monitoring initiative. During this grant period, we will conduct three projects: 1) Effect of stream morphology on denitrification, 2) Effects of point sources (livestock operations) on water quality, and 3) Modification of the Index of Biotic Integrity for use in streams in the Western Corn Belt Plains Ecoregion. We provide a brief summary of activities for each project during the year.

<u>Modification of the Index of Biotic Integrity for use in streams in the Western Corn Belt Plains ecoregion.</u>

The Index of Biotic Integrity has been developed by Karr (Karr 1981, Fausch et al. 1984, Karr et al. 1986) over the last decade as a means of assessing the biological integrity of streams by sampling the assemblage of fish species. Twelve metrics were chosen to comprise the index, combining aspects of individual condition, and population and community composition. This index is considered to be very useful to assess the condition of streams because: 1) it is sensitive to a wide range of anthropogenic stresses, 2) it is quantitative and provides criteria for ranking streams according to their "health", 3) it uses 12 metrics to assess stream condition and does not rely on a single indicator or measure, 4) scores for each metric are recoverable resulting in no loss of information (a loss that sometimes occurs in other indices), 5) expert judgement is incorporated in a systematic and ecologically sound manner, 6) each stream's IBI score is compared to the maximum score attainable based on a survey of streams with minimal disturbance, and 7) it incorporates both spatial and temporal dynamics of the biological system (Miller et al. 1988, Karr 1991).

The IBI has been used successfully in many situations (see Karr 1991 for a brief review), and has been incorporated into the rapid bioassessment protocol for streams and rivers (Plafkin et al. 1989). It has been assigned a high-priority research status as a response indicator for community structure by the inland surface waters working group of EMAP.

The IBI was originally developed for fish stream assemblages in the eastern sections of the midwest. Our recent applications of the original IBI metrics to streams in Kansas and Iowa indicate that this index should be modified before it can be used with confidence in the Western Corn Belt Plains ecoregion. In fact, the IBI was designed so that it can be modified to fit the fish fauna of the region (Miller et al. 1988), and it has been modified successfully and used in a variety of regions in this country as well as Canada and Europe (Miller et al. 1988, Hunsaker and Carpenter 1990).

Consequently, the major objectives of this project are to: 1) modify the IBI for use in the streams of the Western Corn Belt Plains ecoregion, and 2) use the modified IBI to set an appropriate range of scores for rating the biological integrity of streams in the Western Corn Belt Plains ecoregion.

The methodology used in this project is simply to use the fish collected at each sample site within the watersheds as the sample for the modification of the IBI. Each site will be blocked and seined until no fish are captured in the seine hauls. Each site will then be sampled by electrofishing to capture all of the fish unable to captured by seining, thus providing us with a complete sample of the fish at each site. We can then test all of the metrics that have been proposed, as well as any that might seem appropriate for use in the regional IBI, by comparing these metrics with the chemical water quality parameters and remaining biotic variables. Listed below are the quarterly activities for this project.

June 15 - September 30

O Acquire equipment necessary to sample fish - Purchase of seines and electrofishing equipment.

October 1 - December 31

O Autumn fish sampling - Seining and electrofishing as described above.

O Development and examination of metrics - Previous sampling from pilot projects did not include electrofishing and consequently did not provide us with a complete sample of the fish fauna. With the complete sample generated each season, we can adequately examine the original metrics developed for the IBI to determine if they are useful in this region. We will test appropriate metrics from previous modifications, as well as develop new metrics for possible inclusion in the IBI.

January 1 - March 31

O Winter fish sampling (if possible)

O Development and examination of metrics

April 1 - June 15

O Spring fish sampling

O Finish development and examination of metrics

O Development of rating scale for assessment of biological integrity - With the metrics that appear most appropriate for assessing water quality in the Western Corn Belt Plains ecoregion, we can modify the scoring of the metrics to provide a scale for ranking biological integrity based on our own sampling of water chemistry and biological parameters.

<u>Assessment of stream network factors influencing the export of nitrate-nitrogen from rural watersheds</u>

While much progress has been made in examining nutrient transport and transformations in lotic ecosystem, the factors that influence nitrate depletion in streams (thus watershed export) draining rural landscapes are not well understood. A number of studies demonstrated that considerable seasonal and annual nitrate losses occur during transport in agricultural streams (Kaushik and Robinson 1976, Hill 1979, 1983, Hoare 1979, Cooper and Cooke 1984, Jacobs and Gilliam 1985, Bachmann et al. 1989). However, some investigations suggested an absence of significant nitrate depletion in several forest and agricultural streams (Johnson et al. 1976, Triska et al. 1984, Richey et al. 1985). For the most part, recent studies conducted in streams in agricultural watersheds demonstrated that nitrates typically experience a number of biologically mediated transformations. Stream nitrate losses have been associated with nitrate uptake by macrophytes and algae and through denitrification in anaerobic sediments. In stream networks draining agricultural watersheds, the major mechanism of nitrate depletion resulting in decreased nitrate export was denitrification in anaerobic stream sediments (Chatarpaul and Robinson 1979, Swank and Caskey 1982, Hill and Sanmugadas 1985). In addition, our work in rural watersheds of northeastern Kansas indicated that reductions in available nitrogen were occurring in specific instream macrohabitats (e.g. beaver ponds, deep pool areas) (Meador 1990). Two processes were suspected to be involved--photosynthetic algal uptake and bacterial metabolism. Our data suggested that both nitrification and denitrification may have been occurring in beaver ponds. It is known that nitrification and denitrification can occur concurrently in streams, nitrification in the water column and denitification in the benthos (Chatarpaul et al. 1980). Certainly the physical properties of some stream macrohabitat areas (e.g., pools) allow the accumulation of organic materials through depositional processes and often create areas (deep, slow moving water) favorable to the development of anaerobic conditions. Stream areas of high organic carbon storage and frequent anaerobic conditions in the sediment are areas with high denitification rates, and consequently, are important instream habitats in determining nitrate export from the watershed. Pooled areas would provide especially long residence times and warm temperature under low flow conditions thus increasing denitrification efficiency. Hill (1988) found nitrate removal efficiency decreased with increased temperature and increased velocity and flow, due in part to a reduction in the bed area to stream volume ratio and to a reduction in residence times. While many other factors have been associated with instream denitrification processes and rates, the occurrence of anaerobic conditions often associated with certain instream macrohabitats with long residence times are candidates for primary sites where denitrification processes are likely to occur during low flow.

A pilot assessment of the influence of instream macrohabitats or geomorphic features on stream nitrate losses will be initiated during the first year of this grant. These assessment activities will be conducted concurrent with regularly scheduled watershed monitoring and will be conducted only at selected stream segments sites within selected watersheds. Instream habitats and geomorphic features to be sampled at stream segment sites will include long-reach runs (glide areas), riffles and pools; pools formed by debris dams; and beaver pools. These instream areas will be mapped and transect measurements obtained for wetted width, depth, velocity, and substrate composition. In addition, in situ measurements of water temperature, pH, dissolved oxygen, conductivity and redox potential will be taken for the water column and benthic interface along the previously established transect lines used for physical measurements obtained for the study area. Redox potential will be obtained as millivolt readings from the field pH meter equipped with a standard platinum redox electrode. Acid preserved and unpreserved water samples (grab samples) will be collected along the inlet transect, outlet transect and at a minimum of two sites within the study area where stream velocities are reduced. These water samples will be handled in accordance to the procedures already outlined within the QA/QC section of the grant and will be analyzed for nitrate, ammonia, turbidity and chlorophyll *a*.

The volume and water residence times will be calculated from physical and hydrological data obtained from transect measurements. Input/output comparison for nitrate, other chemical and biological parameters will be examined to determine those factors most influencing nutrient losses, if any, during low flow.

Listed below are the quarterly activities for this project.

June 15 - September 30

- Acquire equipment necessary to this project
- Select potential instream study sites during watershed selection process and site visits

O Field test sample procedures and perform laboratory water quality analysis

October 1 - December 31

O Autumn sampling of instream pilot sites selected to assess factors influencing nitrate losses

January 1 - March 31

O Winter sampling (if possible)

O Data reduction and analyses

April 1 - June 15

O Spring sampling

O Data reduction and analyses

Evaluation of near-stream farmstead pollution in rural watersheds

Our previous work on the interrelationship between landscape and water quality in small Kansas streams impacted by rural nonpoint source pollution, identified the occurrence of "point" source pollution in several watersheds (Meador 1990). Although no wastewater treatment plants or large industries were located within the study watersheds, point sources still had a significant impact on water quality and their effects were noticeable during the extreme low flow conditions that existed during the study period. The increased importance of these non-regulated agricultural point sources (i.e. farmsteads with livestock confinement areas) over other, more extensive watershed characteristics (e.g. cropland, pasture) probably arose from the low flow conditions associated with the study period. High flow conditions and runoff tend to dilute or "mask" point source contributions, while low flow (non-runoff) conditions often magnify their impact. Hill (1978) observed this same phenomenon in his study of nitrate export from agricultural and forest/abandoned agriculture watersheds.

The most important point source influences appeared to be associated with livestock operations. Livestock confinements are expected to contribute substantial quantities of pollutants during drought-like conditions because most stormwater (around 90%) runs off of confinement areas due to hard packing of the surface by animals (Dickerhoff and Haith 1983). Confinement area, activity level, distance from the stream, and stream distance to the sampling station were all assumed to be important variables with respect to the influence of point sources on water quality. The hypothesized relationship between these variables was used to create a point source variable which mathematically expressed them in a single value. This point source variable was defined as:

$$[PSVAR]_{station} = \Sigma[\frac{Ac * AL}{Dc + Ds} * 1000]_{300\ m\ radius} + \Sigma[PSVAR]_{upstream}$$

where:

Ac = Estimated confinement area (hectares)

AL = Activity level; inactive = 1, active = 2

Dc = Shortest linear distance from confinement to stream (meters)

Ds = Stream distance to sampling point (meters)

All of the measurements of these attributes were obtained from remotely sensed data (i.e. aerial photography) and ground truthed for accuracy. Thus estimates of the PSVAR variable were easily obtained. Since point sources within a 300 meter upstream radius of the sampling stations appeared to correspond well with observed water quality impacts, only livestock operations within this area were included in the determination of this variable. Each sampling station had a value of PSVAR, although some stations in the upper reaches of the watersheds had a score of zero. PSVAR values from upstream decreased with distance downstream (as Ds increased), and were additive with PSVAR values of a particular sampling station. When these PSVAR values were plotted against stream distance for each of the four study streams, the shapes of these figures appeared to be very similar to some of those observed in water chemistry versus stream distance plots observed earlier in this study.

Correlation coefficients were calculated between watershed PSVAR values and associated untransformed, non-Winsorized water chemistry measurements for each of the four streams (Meador 1990). Correlations between PSVAR values and the water chemistry measurements were excellent in many cases, although results were rather sporadic with respect to each particular constituent. Correlations with turbidity and total suspended solids (TSS) were very strong for three of the streams, suggesting that confinements were sources of particulate pollutants and/or that a strong algal response to increased nutrients occurred downstream from these influences. In general, nearly all of the water chemistry parameters showed strong positive correlations with PSVAR values within most watersheds. These data suggested that livestock operations were exerting a major influence on the concentrations of many of the water chemistry parameters measured during the low-flow period.

Based on available data from Meador's study (Meador 1990), it was concluded that stream segments downstream of large livestock operations (confinements $>$ 1 hectare) which are within 150 meters of the stream should be examined for potentially causing unacceptable reductions in water quality. In one instance, locating a large livestock confinement adjacent to a stream appeared unacceptable as evidenced by the highly degraded water quality conditions observed downstream of the North Elm Creek dairy operation (station 7). Smaller livestock operations would appear to be of concern only when confinements are located close to the stream. Locating confinements on high runoff potential soils may be unwise, although livestock areas are usually hard packed and this might be more of a concern for the land between the confinement and the stream. Nearby ditches or tributaries may exacerbate water quality problems by increasing pollutant transport from these confinements. The use of a GIS approach utilizing landscape variables and associated stream water quality variables in identifying rural point source impacts appears to be new, and no previous studies documenting these relationships were found in the literature. These results strongly suggest that a more intensified examination of PSVAR needs to be undertaken. The proposed project will attempt to refine the results from Meador (1990) by investigating additional factors that contribute to point source contamination from livestock confinements, and developing a more reliable and predictive PSVAR variable.

The preliminary evaluation of point source impacts on water quality during low flow conditions will be incorporated into the watershed monitoring initiative. The primary objective of the assessment will be the identification of additional point source attributes that better define their relationship with downstream water quality. In order to accomplish this objective the following activities will be initiated during the grant.

1) Photointerpretation and mapping of all watershed properties (e.g., farmsteds, livestock confinements), and identification of attributes (e.g., current confinement usage).

2) Establish and map correct drainage route from properties to the streams. Drainage distances will be substituted for the "shortest distance measure" currently used in the PSVAR variable.

3) All near-stream properties will be ground truthed for agreement with the photointerpreted data. Additional property attributes will be assessed at ground level including number and type of livestock confined, presence of septic fields, and other property variables that may contribute to point source pollution.

4) Monitor stream water quality above and below probable drainage routes from selected near-stream properties. Only turbidity, ammonia, nitrate, conductivity, pH, and dissolved oxygen measurements will be taken at these additional sites. Water quality analyses and measurements will be in accordance with those procedures listed in the workplan.

These data will be analyzed to evaluate the utility of a PSVAR variable in identifying the potential of property to contribute to point source pollution in watersheds. Provided below is a list of quarterly activities.

June 15 - September 30

- Acquire computer and digitizing equipment
- Obtain aerial photography for watersheds and begin to build property layers for GIS database

October 1 - December 31

- Autumn water quality sampling and point source drainage sampling
- Data reduction
- Continue building GIS database
- Ground truth properties

January 1 - March 31

- O Winter sampling (if possible) for water quality
- O Data reduction and analyses

April 1 - June 15

- O Spring water quality sampling
- O Prepare year-end report of activities for EPA

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